F1-270

UNIVERSITY OF CALIFORNIA, BERKELEY

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SPONSORED PROJECTS OFFICE

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July 28, 1997

JUL 28 1997

Kate Hansel
CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Dear Ms. Hansel:

Enclosed is a proposal submitted on behalf of The Regents of the University of California, Berkeley entitled "Irrigation Drainage Water Treatment of Selenium Removal: Los Banos Demonstration Facility," to be conducted under the direction of Professor William Oswald.

I am the University representative to whom questions my be directed and with whom contractual negotiations may be conducted. I can be reached at (510) 643-6113 or by e.mail at ldeetz@uclink2.berkeley.edu. Contract and grant documents must be issued in the University's corporate name, i.e., The Regents of the University of California, c/o Sponsored Projects Office, 336 Sproul Hall, University of California, Berkeley, CA 94720-5940.

Due to the late receipt of this proposal in our office, we have not had the opportunity to fully review its content. We are processing the proposal in order to meet your deadline. While we expect to find that it meets all University of California requirements, if anything in the proposal is found to be unacceptable we will notify you in writing and reserve the right to withdraw it from further consideration if necessary.

Sincerely,

Lynn E. Deetz

Lynn E. Deetz
Senior Research Administrator

Enclosure

cc: Professor Oswald
Laurel Holland

F1-270

JUL 28 1997

*Proposal From*

**The Regents of the University of California**
c/o Sponsored Projects Office
University of California, Berkeley Campus
Berkeley, California 94720

*to*

**CALFED Bay-Delta Program**
1416 Ninth Street, Suite 1155
Sacramento, CA 95814
Attn: Ms. Kate Hansel

*Entitled*

# IRRIGATION DRAINAGE WATER TREATMENT FOR SELENIUM REMOVAL: LOS BANOS DEMONSTRATION FACILITY

EEHSL - 2018

| | |
|---|---|
| Principal Investigator: | Emeritus Prof. William J. Oswald<br>Dept. of Civil & Environmental Engineering<br>Env. Engineering and Health Sci. Laboratory<br>1301 S. 46th Street, Bldg. 112<br>Richmond, CA 94804-4603<br>(510) 231-9438<br>(510) 231-5764 fax |
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| Tax Status: | Non-Profit |
| Tax Identification Number: | 946002123 |
| Collaborators: | Lawrence Berkeley Laboratory, DWR, construction |
| Project Group Type: | Other Services |


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Prepared by Environmental Engineering &
Health Sciences Laboratory
July 28, 1997

## II. EXECUTIVE SUMMARY

Approximately 200,000 gallons per day of irrigation drainage water will be treated by the proposed Algal Bacterial Selenium Removal (ABSR) Facility at the Los Banos Desalting Facility site. The ABSR Facility will serve to demonstrate to water districts, growers, and regulators the performance and economics of the ABSR Process. The Los Banos Facility will be a 20-fold scale up from the existing ABSR Facility in the Panoche Drainage District where total soluble selenium concentrations have been reduced 90% to as low as 34 $\mu g/L$. In past studies total soluble selenium concentrations have reached less than 10 $\mu g/L$ in ABSR Systems (Gerhardt and Oswald, 1990). The estimated cost of drainage water treatment by the ABSR Technology is less than $100 per acre-ft in systems larger than 10 million gallons per day (SOA, Inc., 1988).

In the ABSR Technology ponds are used to both produce selenium- and nitrate-reducing bacteria and to produce and harvest microalgae for bacterial substrate. The Reduction Pond (RP) receives tile drainage water and organic bacterial substrates including algae. Native bacteria such as *Acinetobacter* and *Pseudomonas* use the substrates as a carbon and energy source and reduce oxygen, then nitrate, and finally selenate. The second pond in the series is a 0.1-acre shallow, paddle wheel-mixed High Rate Pond (HRP) which is designed to maximize the growth of green microalgae. The algae are collected in an Algae Settling Pond (ASP) that follows the HRP. These algae are harvested and then added to the RP for use as bacterial substrate.

It is proposed to construct, operate, and evaluate an ABSR Facility during three years. During this period, systematic studies utilizing the two ABSR Systems will be conducted to improve and optimize selenium removal at the lowest possible cost.

With the wide-spread implementation of the ABSR Technology in the western San Joaquin Valley the loading of selenium to the San Joaquin River and the Delta would be substantially reduced lowering the potential for toxic impacts upon wildlife.

## LIST OF FIGURES

## III. PROJECT DESCRIPTION

### A. DESCRIPTION AND APPROACH

In order to prevent toxicity to wildlife, the San Joaquin Regional Water Quality Control Board and the U.S. EPA have set limits on selenium concentration and loading to the sloughs draining western San Joaquin Valley agricultural areas. Presently the sloughs discharge selenium-contaminated subsurface drainage water to the San Joaquin River and the Delta. Drainage water treatment can effectively reduce mass loading of selenium to the San Joaquin River from agricultural sources. Discharge of selenium to the San Joaquin River by farmers in the 90,000 acre Grasslands basin is limited by regulation to 6,800 lbs per year. To meet this limit half of the selenium mass must be eliminated. Short of extensive land retirement drainage water treatment is currently the only practical means of reducing the selenium load.

### ALGAL-BACTERIAL SELENIUM REMOVAL SYSTEM

An Algal-Bacterial Selenium Removal (ABSR) System has consistently removed 70% to 80% of total soluble selenium from a flow of 3,200 gallons per day of subsurface agriculture drainage water in the Panoche Drainage District (PDD) near Firebaugh, California. Recent removals have reached 90%. The ABSR Facility to be constructed at the Los Banos site will incorporate design advances developed at the Panoche ABSR Facility that will improve the substrate utilization efficiency and increase selenium mass removal. Total soluble selenium concentrations have reached less than 10 ppb in the ABSR Process (Gerhardt and Oswald, 1990). The estimated cost of drainage water treatment is less than $100 per acre-foot in systems larger than 10 million gallons per day (SOA, Inc., 1988). Smaller ABSR Facilities treating drainage water from individual sumps with especially high selenium concentrations might also prove to be economical. Removal of boron and some metals also has been observed in the ABSR Process.

### RENOVATIONS AT THE LOS BANOS SITE

Approximately 200,000 gallons per day will be treated by the proposed ABSR Systems at the Los Banos Desalting Facility site. Two ABSR Systems will be constructed to accommodate seasonal changes in drainage flow and to allow simultaneous evaluation of different operational parameters. The ABSR Facility will be constructed to utilize the two existing 0.6-acre solar ponds and 10 acres of the existing marsh ponds. The marsh ponds will be renovated as two High Rate Ponds (HRPs) designed for high productivity algae cultivation. The internal berms will be removed and the floor leveled and surfaced with asphalt paving or plastic liner. The lining is necessary in this demonstration system to perform mass balances on contaminants. Divider walls will be installed to form two serpentine channels approximately 38 feet wide. A paddle wheel station in each HRP will circulate the pond water around the channel circuit at a low velocity of 0.5 feet per second. This circulation is essential for maintaining high algal productivity. Each HRP will have two 5-feet deep carbonation sumps where engine exhaust or pure carbon dioxide will be diffused to provide carbon for algal growth.
Harvesting of algae from the HRP effluents will be accomplished by four Settling Ponds and one dissolved air flotation (DAF) unit. The 0.14-acre Settling Ponds will be constructed to have an average depth of 8 feet.

The existing solar ponds will be modified to become Reduction Ponds. Pond A is a 12.5-feet deep earthen basin lined with a scrim-reinforced plastic liner and a water volume of 1.6 million gallons. For the new work, this pond will be retrofitted by the addition of an internal vertical baffle and a surface cover, both constructed from plastic liner. Pond B is identical to Pond A except that most of its liner has deteriorated and must be replaced. Therefore, the basin of Pond B will be excavated to a depth of 25 feet and relined. The new Reduction Pond B will have a liquid volume of 2.4 million gallons, a surface cover, and an internal baffle.

The algae cells may need to be disrupted for efficient utilization as bacterial substrate. Current research to be completed by December 1997 will determine whether this pretreatment step is justified economically. If pretreatment is found to be cost effective, the concentrated algal slurry harvested from the Settling Ponds and the DAF at Los Banos will be heated to 70°C prior to being fed to the Reduction Ponds as substrate. The heat source will be waste heat from an on site engine generator which will also produce carbon dioxide for algal production and electricity for system operation.

**B. LOCATION**

The Los Banos Site is located approximately 5 miles from the City of Los Banos on State Highway 152 in Fresno County. The technology demonstrated at this site if implemented on a large scale in the western San Joaquin Valley would significantly reduce the selenium load to the San Joaquin River north of Mud Slough and to the Delta.

**C. EXPECTED BENEFITS**

Selenium contamination of the San Joaquin River and Delta is a likely stressor for invertebrate aquatic organisms such as clams and for the higher animals that feed on them. The selenium load from subsurface agricultural drainage affects both fresh water and salt water habitats. By reducing the loading of selenium to the San Joaquin River and the Delta, acute and/or chronic toxicity to wildlife would likely be reduced. To this end the San Joaquin Regional Water Quality Control Board and the U.S. EPA have set a selenium limit of 5 $\mu$g/L for drainage discharged to sloughs in western San Joaquin Valley agricultural areas. Presently the sloughs discharge selenium-contaminated subsurface drainage water to the San Joaquin River and the Delta.

The proposed 200,000 gallon per day demonstration ABSR Facility is expected to remove approximately 300 g of total soluble selenium and 68 kg of nitrate nitrogen each day from the drainage water in the Grasslands Bypass. With the future implementation of the ABSR Technology to treat substantial portions of the drainage flows of the western San Joaquin, reductions in selenium loading to the San Joaquin River will be significant. With 10 million gallons per day being treated in ABSR Facilities, 15,000 g/day of selenium would be prevented from entering the San Joaquin River system and the Delta.

**BENEFITS OF ABSR FACILITY**

Demonstration and refinement of the ABSR Process at Los Banos will provide accurate capital and operational information needed by drainers prior to larger-scale, wide-spread implementation. Of the selenium removal processes tested over the past decade, the ABSR Process is one of the most cost effective for agricultural drainage treatment for the following reasons:

- Low capital cost relative to physico-chemical technologies such as ion exchange and membrane systems.

- Low operational costs. Nitrate- and selenium-reducing substrates are produced on-site or consist of locally available organic wastes.

- Infrequent need for disposal of reduced selenium that is immobilized in inert sediments.

- Potential utilization of sediment containing reduced selenium as soil amendment.

## D. BACKGROUND AND BIOLOGICAL/TECHNICAL JUSTIFICATION

### THE ABSR PROCESS

The basic concept of the ABSR Process is to grow microalgae on drainage water to remove nitrate and to utilize the algal biomass as a carbon source for bacteria which reduce selenate to selenite in an anoxic Reduction Pond (RP). Selenite precipitates with metal ions or is further reduced to insoluble elemental selenium. The insoluble forms of selenium are separated from the drainage water primarily by sedimentation in the RP and secondarily by dissolved air flotation (DAF) and sand filtration. The flow schematic of the ABSR Process is shown in Figure 1.

Past and current studies indicate the necessity of reducing nitrate to low levels before selenium can be reduced. Once the nitrate level is reduced, selenate can be reduced to selenite and elemental selenium by bacteria that use the oxidized selenium species as electron acceptors for respiration (Gerhardt & Oswald, 1990; Oswald, 1988). A carbon source is required for the reduction of nitrate to nitrogen gas. We have determined, however, that high sulfate concentrations (2,000-4,000 mg/L as $SO_4^{2-}$) in drainage water do not appear to significantly interfere with nitrate and selenium reduction.

The selenium removed from the water column accumulates in the algal-bacterial biomass and inert materials in the bottom of the RPs. Because the biomass is continuously decomposing, the volume of solid residues increases very slowly. These solid residues can accumulate over many years before they are removed and disposed of at a landfill. With frequent removal of solids from the RPs, selenium concentrations are expected to be low enough to allow land application. The residual solids containing high levels of nitrogen, phosphorus, and selenium could be beneficial as a soil amendment on the selenium-deficient soils of the eastern San Joaquin Valley.

Algae grown in the HRPs provide an on-site carbon and energy source for nitrate-reducing and selenium-reducing bacteria. Other organic carbon sources might be used in place of, or in addition to, algal biomass. Low-cost food processing wastes may also be a carbon source for this application as has been determined in the current studies at the PDD. Dissolved carbon dioxide produced by on-site power generation units can be used in the HRPs to stimulate algal growth. This carbon improves algae production by supplementing the bicarbonate in the influent drainage water. Carbon dioxide is currently being used as a carbon source at the ABSR

Facility at the PDD and has been used since 1983 as a carbon source in HRPs used for commercial algal cultivation (Naylor, 1993).

The algae grown in the HRPs will be harvested primarily in Algae Settling Ponds (ASPs) and secondarily by DAF and filtration as required by effluent discharge standards. The harvested algae are then fed to the RPs for use as bacterial substrate.

Bioaccumulation of selenium by invertebrates and other wildlife is expected to be limited. Influent selenium is captured in reduced form in the sediments of the Reduction Ponds which will be 10 feet below the water surface in Reduction Pond A and 23 feet below the surface in Reduction Pond B. Although invertebrates may be exposed to these deep sediments, movement of selenium into higher animals will be limited in the 10-foot deep Reduction Pond A by a surface cover on the Reduction Ponds which will prevent bird access to any invertebrates. The greater depth in the Reduction Pond B will prevent bird access to benthic invertebrates.

Inorganic and organic selenium levels in the HRPs and ASPs should be similar to those found in the subsurface drainage channels where microalgal growth is prevalent.

The ABSR Process is a variation of the Advanced Integrated Wastewater Pond System (AIWPS) technology which has been developed by Professor W.J. Oswald at the University of California, Berkeley Environmental Engineering and Health Sciences Laboratory (EEHSL) for economical and natural treatment of sewage and industrial and agricultural wastes.

An small-sclae pilot ABSR Facility was constructed and operated from 1987-1989 near Mendota, California, and its ability to remove high concentrations of selenium and nitrate from agricultural drainage was proven. Reductions in total selenium concentrations from 400 $\mu$g/L to less than 10 $\mu$g/L were achieved. These studies also elucidated several key microbiological and physico-chemical mechanisms for selenium and nitrate removal (Gerhardt and Oswald, 1990; Gerhardt *et al.*, 1991; Lundquist *et al.*, 1994). Based on this and other earlier research, an ABSR Facility with a design flow of 20,000 gallon per day has been built near Firebaugh in the PDD to demonstrate at a larger scale the feasibility and economy of selenium and nitrate removal from irrigation drainage water.

A preliminary economic analysis based on the work at Mendota indicated that construction and operations costs of an ABSR Facility should be between $68 and $272 per acre-foot treated for 100 and 1 million gallon per day systems (1988 dollars) (SOA, Inc., 1988).

**THE ABSR FACILITY AT THE PANOCHE DRAINAGE DISTRICT**

An Algal-Bacterial Selenium Removal (ABSR) Facility has been constructed and operated for a year in the Panoche Drainage District (PDD) near Firebaugh, California. Support for the design, construction, and operation of the Panoche ABSR Facility has been provided by a U.S. Bureau of Reclamation Challenge Grant Program and matching funds and services have been provided by the PDD, the University of California, Berkeley, and Lawrence Berkeley National Laboratory. The Facility consists of two identical ABSR Systems. One ABSR System is used as an experimental control. Each system consists of a series of ponds designed both to produce selenium- and nitrate-reducing bacteria and to produce bacterial substrate. The Reduction Pond (RP) receives tile drainage water and organic bacterial substrates. Native bacteria such as *Acinetobacter* and *Pseudomonas* use the substrates as a carbon and energy source and reduce oxygen, then nitrate, and finally selenate. As we demonstrated at the Mendota pilot system, before significant selenate reduction can occur nitrate must be reduced to less than approximately

3 mg/L as N. Nitrate ranges from the 60 to 120 mg/L $NO_3^-$-N in the drainage water at the PDD site. The second pond in the series is a 0.1-acre shallow, paddle wheel-mixed HRP which is designed to maximize the growth of green microalgae. The algae are collected in a 1,400-square foot ASP that follows the HRP. These algae are harvested and then added to the RP for use as bacterial substrate. We have used heating or drying and milling to disrupt the algal cells making them more available to bacterial utilization. However, recent work indicates that these pretreatments may be unnecessary if the algae are collected, harvested, and fed to the RPs in a cycle of days rather than weeks as initially done for the ABSR Systems at the PDD.

## WATER QUALITY RESULTS AND SUBSTRATES EVALUATED

The first objective of the project is to demonstrate the removal of nitrate and selenate by the RPs. For start up, the PDD systems were fed algae collected over six months from the High Rate Pond/Algae Settling Pond system at the University of California, Berkeley Richmond Field Station. These algae were pretreated with heat or by drying and milling. This algal biomass was found to be a relatively poor substrate. Between the time that a surface cover was installed on the South RP in December 1996 and April 1997 when the feeding of Richmond algae was discontinued, the South RP removed on average only 24% of influent nitrate in a hydraulic residence time of 65 days. The mean removal of nitrate was 17 mg/L $NO_3^-$-N with the lowest effluent concentration being 36 mg/L $NO_3^-$-N. With improved substrate utilization and with the installation of internal baffles in the RPs, it is expected that the hydraulic residence time in the RPs can be dropped to approximately 20 days.

Subsequent laboratory experiments have shown that algae harvested directly from the Panoche and Richmond HRPs and used as substrate directly without pretreatment are 2 to 11 times more effective for nitrate and selenium reduction as were the algae collected over months in the Richmond ASPs. The "fresh" algae reduced at least 0.11 gram $NO_3^-$-N per gram volatile solids introduced. Steam pretreatment of the "fresh" algae did not significantly improve nitrate reduction. Molasses was also evaluated as a substrate and found to reduce 0.22 gram $NO_3^-$-N per gram volatile solids.

Acting on the laboratory results, animal feed-grade molasses has been used as a substrate in the North ABSR System and freshly harvested algae in the South ABSR System. From March 24 to June 9, 1997, the molasses-fed system has consistently reduced nitrate nitrogen to less than 10 mg/L $NO_3^-$-N and has reduced total soluble selenium 70% to 80%. The influent had a mean total soluble selenium concentration of 377 $\mu$g/L and the effluent had a mean concentration of 96 $\mu$g/L (Figures 2 and 3). Additional soluble selenium removal is acheived in the HRP and ASP. The lowest systemm effluent total soluble selenium concentration was 34 $\mu$g/L. The flow has been 3,200 gallons per day during this period, giving a hydraulic residence time of 52 days in the molasses-fed system. A hydraulic residence time of approximately 20 days or less is expected to give equal results once internal baffles are installed in the RPs in August 1997.

Algae harvested by dissolved air flotation from the City of Sunnyvale wastewater treatment ponds have been fed to the South ABSR System since April 14, 1997 resulting in complete nitrate removal. Soluble selenium concentration in the South RP effluent has dropped to 133 $\mu$g/L (Figure 4). Now that the nitrate level in the South RP has been reduced to near zero, importation of Sunnyvale algae will be discontinued and algae harvested from the South

HRP will fed to the RP to denitrify the influent. Also gradual improvement in nitrate-reducing ability of the RP culture was seen at the Mendota pilot system and is anticipated at the PDD Facility.

The ABSR Facility HRPs reached algae concentrations as high as 493 mg/L as volatile suspended solids (VSS) before wind storm damage forced the draining of the HRPs at the end of March 1997. Concentrations have ranged from 80 to 150 mg/L VSS since the HRPs were put back on line. Approximately 50% of the algae has been settling in the Algae Settling Ponds. This settling efficiency is typical of algae growth in paddle wheel-mixed ponds. The algae produced in the molasses-fed system will be recycled to the RP reducing the molasses dose required.

The internal baffle in each of the RPs planned for Los Banos should improve nitrate and selenium removal. The baffles will prevent flow short circuiting which is the likely reason for the leveling off of selenium removal at 70% to 80% in the molasses-fed RP at the PDD. The cells formed by the baffles will also isolate the selenium reducing zones from dissolved oxygen and nitrate present in the influent.

## LESSONS FROM THE PANOCHE ABSR FACILITY APPLIED TO THE LOS BANOS FACILITY

The design of the Los Banos ABSR Facility will be enhanced by the operational experience gained from the PDD ABSR Facility. Unlike the RPs at the PDD, the Los Banos RPs will be constructed with internal baffles to prevent flow short circuiting and to provide nitrate-reducing zones that are isolated from dissolved oxygen in the influent. Dissolved oxygen inhibits denitrificaton and selenium reduction. The surface covers budgeted for Reduction Ponds at Los Banos will prevent wind-mixing of high dissolved oxygen surface water to the anoxic bacterial reduction zones. However, the existing damaged ground liner in Solar Pond B provides the opportunity to construct a deeper RP that would be typical of a large-scale ABSR Facility. The combination of the 23-feet depth and the isolated zones formed by the baffle may eliminate the need for a surface cover on Reduction Pond B and the associated cost.

The HRPs planned for Los Banos are larger relative to the drainage flow than those at PDD. This modification will both produce more algal biomass per influent nitrate mass, and it will result in more nitrate removal by algal assimilation than is possible in the PDD system.

The modifications described promise to significantly improve the performance and lower the operational costs of the Los Banos ABSR Systems relative to those at PDD. The 20-fold increase in treated flow will provide additional scale-up information for subsequent ABSR Facility designs.

## E. PROPOSED SCOPE OF WORK

The objective of the proposed work on the ABSR Technology is to demonstrate the production and subsequent use of microalgae as a substrate for nitrate and selenium reduction. The operational costs of full-scale ABSR Facilities will be estimated from the results providing valuable planning information for drainage districts and the State and Federal governments. The specific activities of the Los Banos ABSR Facility project are as follows:

Task 1 (Year 1)

Summary: Renovate the existing ponds (Pond A, Pond B, and 22 of the 33 shallow Marsh ponds) at the Los Banos Desalting Facility Site to construct the 200,000 gallon per day ABSR Facility.

- Subtask 1.1 Complete final design, construction drawings, and construction bid procurement and administration.
- Subtask 1.2 Repair Pond A liner as needed; install vertical plastic baffle; and, install plastic surface cover.
- Subtask 1.3 Excavate Pond B to 25 feet of depth; install ground liner and vertical plastic baffle.
- Subtask 1.4 Construct High Rate Ponds by leveling 10 acres occupied by 22 of the 33 marsh ponds by installing ground liner, channel divider walls, and paddle wheel stations.
- Subtask 1.5 Construct four Algae Settling Ponds totaling 0.5 acres.
- Subtask 1.6 Install High Rate Pond carbonation and algae pretreatment system.
- Subtask 1.7 Install plumbing, pumps, and additional appurtenances.
- Subtask 1.8 Start up ABSR Facility.

Task 2 (Year 2 and Year 3)

Summary: Collect the data required to perform selenium, nitrogen, phosphorus, and carbon mass balances on the systems in order to validate the removal performance. Determine attainable steady-state selenium concentrations in the effluent of the ABSR Systems. Adjust operational parameters (HRP depth, pH control set point) to most efficiently use nutrients for algal growth.

- Subtask 2.1 Monitor influent and effluent flows and selenate and selenite concentrations in each pond, the inorganic and organic selenium concentrations in the pond sediments, and any volatilized selenium captured in pond surface collectors. Water and gas samples will be analyzed weekly. Pond sediments will be analyzed quarterly by X-ray absorption near-edge structure (XANES) spectroscopy at Brookhaven National Laboratory.
- Subtask 2.2 Monitor the ammonia, organic, nitrate, and nitrite forms of nitrogen in the influent and effluent of each pond and in the pond sediments. Gas samples collected at the pond surface will be analyzed for nitrogen gas. Influent, effluent, and gas samples will be analyze weekly. Sediment samples will be analyzed bimonthly.
- Subtask 2.3 Monitor the total and soluble reactive phosphorus in the influent

and effluent of each pond and in the pond sediments. Influent, effluent, and gas samples will be analyze weekly. Sediment samples will be analyzed bimonthly.

Subtask 2.4 Monitor the organic and inorganic carbon in the influent and effluent of each pond and in the pond sediments. Gas samples captured from the pond surfaces will be analyzed for carbon dioxide and methane gas. Influent, effluent, and gas samples will be analyzed weekly. Sediment samples will be analyzed bimonthly.

Subtask 2.5 Monitor dissolved hydrogen sulfide concentrations in the Reduction Ponds.

Subtask 2.6 All water quality analyses will be validated with QA/QC procedures using matrix spikes, split and duplicate samples, blanks, and standards.

Task 3 (Year 2 and Year 3)

Summary: Sample system water column and sediments twice yearly and determine the bacterial types active in nitrate and selenium biotransformations. Determine the environmental conditions that optimize the organisms' biotransformation reactions.

Task 4 (Year 2 and Year 3)

Summary: Quantify invertebrate populations in the ponds and measure selenium bioaccumulation levels. Compare to published information on background levels of bioaccumulation in the western San Joaquin Valley and on levels causing selenium toxicity.

Subtask 4.1 Conduct bimonthly samplings of invertebrates in all ponds and analyze the biomass for selenium concentration.

Task 5 (Year 3)

Summary: Use the data collected to provide an economic analysis of the ABSR Facility at Los Banos and of the ABSR Technology applied at a larger scale (e.g., 1 million gallons per day (MGD), 10 MGD, and 100 MGD).

Subtask 5.1. Maintain records of operational costs such as power, engine generator fuel use, nutrient costs (phosphorus, iron), and operations and maintenance costs.

Task 6 (Year 1, Year 2, and Year 3)

Summary: Conduct field days at the ABSR Facility for growers, water districts, and regulators. One field day will be held in Year 1, and at least two field days will be held in each of Year 2 and Year 3.

Task 7 (Year 1, Year 2, and Year 3)

Summary: Prepare annual progress reports and a final project report which present and interpret all analytical, quality control, and operational cost data.

## F. MONITORING AND DATA EVALUATION

The program for monitoring the system performance is described above in the Proposed Scope of Work. Data evaluation will consist of determining the effectiveness the system for nitrate and selenium removal and determining accurately the operational costs for achieving the contaminant removal. Laboratory quality control/quality assurance procedures and system mass balances will be used to verify the veracity of the results. The final report will contain cost estimates for large and small flow configurations of the ABSR Technology and will make recommendations on the most appropriate implementation strategy for reducing selenium loads to the San Joaquin River.

Each annual report will be peer reviewed by at least one member of each of the following professions: academic researcher, water district manager, and resources regulator. Their feedback will be published with responses in each annual report.

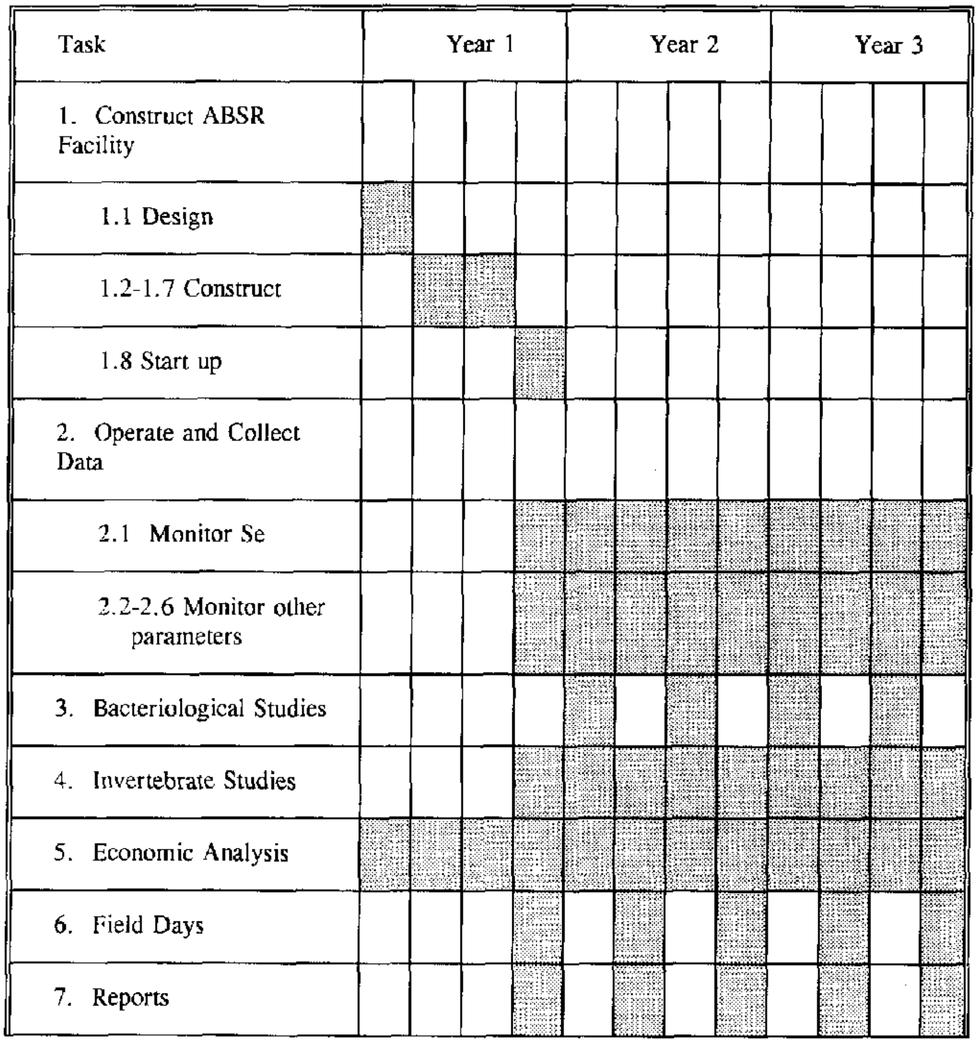
## G. IMPLEMENTABILITY

The site of the Los Banos Desalting Facility is an ideal location for the ABSR Technology. The area available at the site is more than adequate. Existing ponds can be modified and used to construct the ABSR Facility. The site has been used for large-scale drainage water treatment activities in the past, and year-around subsurface drainage water is available adjacent to the site from the San Luis Drain. The San Luis and Delta Mendota Water Authority has expressed interest in utilizing the site for development of a center for drainage water treatment interest of which the ABSR Facility could be the first component. Clean up of existing contaminated soils at the site might be accomplished as part of the construction of the system with considerable potentially savings. Although the Los Banos is the optimal site other sites are under consideration as a contingency.

The PDD and Enrico Farms, Inc. are currently hosting a smaller-scale demostration of the ABSR Process. The Imperial Irrigation District near the Salton Sea has also expressed continued interest in the Panoche ABSR Facility project. Such water districts will likely be the end users of the ABSR Technology and the continued support and interest of water districts and growers will be solicited throughout the proposed Los Banos project.

## B. MILESTONES

Schedule for the Los Banos ABSR Facility Project




## C. THIRD PARTY IMPACTS

There are no anticipated negative third party impacts. All ponds will be lined preventing drainage water contaminants from entering the soil, and high-selenium residual solids will be disposed of in an appropriate landfill.

## V. APPLICANT QUALIFICATIONS

**ORGANIZATION**

Professor William J. Oswald, Ph.D., P.E., originator of the ABSR Process and algal cultivation in High Rate Ponds, will be the principal investigator for proposed ABSR Facility project. Professor Oswald also be the lead designer of the Los Banos ABSR Facility. The engineering and construction of the system should not pose any unusual challenges. Ponds of type proposed--covered ponds with internal baffles and paddle wheel-mixed High Rate Ponds--have been constructed at this scale many times. Professor Oswald will be assisted in project management by two staff research engineers from the Univerisity of California, Berkeley, Environmental Engineering and Health Sciences Laboratory. The staff engineers have 10 and 8 years of experience with the ABSR Technology and similar wastewater treatment processes.

ABSR Facility operations will be performed by a full-time academic staff person from the University of California, Berkeley assisted by the staff research engineers. Analytical work will be conducted by graduate students in the University of California, Berkeley Civil and Environmental Engineering Department and the School of Public Health under the supervision of a managing analytical chemist from the Lawrence Berkeley National Laboratory. The analytical methods to be used are all well established, and the required laboratories and analytical instruments are available at the University of California, Berkeley Environmental Engineering and Health Sciences Laboratory and the Earth Sciences Division of the Lawrence Berkeley National Laboratory.

Identification and characterization of the microorganisms of the Los Banos ABSR Systems will be performed by the laboratory of Professor Terrance Leighton, Ph.D. of the Department of Molecular Cell Biology at the University of California, Berkeley. Professor Leighton's group has previously identified selenium- and nitrate-reducing bacteria from agricultural drains and from the Panoche ABSR Systems. Professor Leighton has also developed a bacterial selenium removal process specifically for the oil refining industry.

Selenium speciation and quantification in the solid residues of the ABSR Systems will be performed by Dr. Tetsu Tokunaga of the Earth Sciences Division of the Lawrence Berkeley National Laboratory using X-ray absorption near-edge structure (XANES) spectroscopy. Dr. Tokunaga is an geochemist with over ten years experience in selenium-related soil studies at Kesterson Reservoir and other sites.

Dr. Nigel Quinn of the Earth Science Division of the Lawrence Berkeley National Laboratory and the U.S. Bureau of Reclamation is an expert in San Joaquin Valley drainage management and real-time monitoring of water quality. He has eight years exerience in San Joaquin Valley drainage issues. Dr. Quinn will evaluate the role the ABSR Facilities can play in conjunction with other drainage management strategies in reducing selenium loads and concentrations across the western San Joaquin Valley. This management evaluation will be valuable to water districts as they look to implement the ABSR Technology in the most effective manner.

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Professor Emeritus of Public Health
and Environmental Engineering
Environmental Engineering and Health Sciences Laboratory
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**EDUCATION**

- Bachelor of Science - Civil Engineering
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- Master of Science - Sanitary Engineering
  University of California
- Doctor of Philosophy - Sanitary Engineering, Biology and Public Health
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**PROFESSIONAL**

- Registered Civil Engineer, State of California
- Sanitary Engineering Director, U.S. Public Health Service
  (Inactive Reserve)
- American Academy Environmental Engineers, AAEE Certified

**AFFILIATIONS**

- American Academy of Environmental Engineers, Diplomate
- American Society of Civil Engineers, Fellow, Life Member
- American Association for the Advancement of Science (Fellow)
- New York Academy of Science
- Water Pollution Control Federation
- American Water Works Association, Life Member
- Interamerican Society of Sanitary Engineers
- International Cell Research Organization

**HONORARY SOCIETIES**

- Chi Epsilon
- Sigma Xi
- Tau Beta Pi
- Delta Omega

**AWARDS AND HONORS**

- Water Pollution Control Federation:
  Harrison Prescott Eddy Medal for Noteworthy Research.
- American Society of Civil Engineers:
  Outstanding Faculty Award (Student Chapter), U.C. Berkeley
  James Croes Medal (National)
  Rudolf Hering Medal (National)
  Arthur M. Wellington Award (National)
- U.S. Bureau of Reclamation, The Environmental Protection Agency and the Department of Water Resources: Special Commendation for Excellence of Consulting Services on Interagency Central Valley Drainage Project.
- Council for Agricultural Planning and Development, Republic of China: Distinguished Paper Commendation.
- National Science Foundation and World Health Organization: Various fellowships for International Speaking Engagements and Consultantships.



I-005879

**SPECIALTIES**

- Sanitary/Environmental Engineering
- Applied Phycology
- Microbial Waste Management Systems
- Environmental Systems Engineering

**EXPERIENCE**

- **Teaching** - Emeritus Professor of Biomedical and Environmental Health Sciences and Environmental Engineering, School of Public Health and College of Engineering, University of California, Berkeley. Specialist in water quality management and low-cost appropriate technology for waste treatment and disposal systems, anaerobic digestion, solar energy applications and alternative energy resource recovery systems. Has taught: Water Resource Engineering (Quality), Principles of Sanitary Engineering, Environmental Health Science (Water and Wastewater), Biological Control Systems, Pond Design and Applied Phycology. Former Major Field Adviser in Bioengineering. Major Professor for more than 50 Master of Science and MPH, and 25 Doctor of Philosophy and Doctor of Public Health graduates.

- **Research Engineer** - In addition to responsibilities associated with his university emeritus professorship, has had more than fifty international, federal, state and local research and development grants as a Research Engineer to study various aspects of microbiological systems for waste treatment, environmental control, energy production, methane fermentation, fertilizer production, pharmaceutical production, water and nutrient reclamation, and toxic waste treatment. Current research involves applications of Advanced Integrated Pond Systems for energy conservation and toxicant removal.

- **Professional Engineer** - Has provided system designs for more than 50 successful wastewater management systems. Has provided advisory, review and consultative services for more than 35 years on water supply and waste management systems, biological engineering and environmental control to the World Health Organization, The Pan American Health Organization, the United Nations Environmental Program, the International Bank for Reconstruction and Development (World Bank), the Asian Development Bank, the U.S. Agency for International Development, the U.S. Army, Navy and Air Force, the U.S. Bureau of Reclamation, United States Congress, House and Senate, Office of the President, U.S. Public Health Service, U.S. Department of the Interior, U. S. Department of Agriculture, the National Academy of Sciences, the National Academy of Engineering, the National Aeronautic and Space Administration, the California State Legislature and California State Department of Water Resources; the Oceanic Institute of Hawaii, the governments of Australia, Bolivia, Brazil, Chile, Colombia, Cuba, Czechoslovakia, Egypt, France, Germany, Hungary, India, Israel, Jamaica, Mexico, People's Republic of China, Philippines, Portugal, Puerto Rico, Russia, Singapore, Sweden, Taiwan, Tunisia, and Venezuela, as well as over 100 local agencies and private firms. Professor Oswald is known internationally as one of the world's foremost authorities on waste stabilization ponds, high rate ponds, methane fermentation, microalgal production, water reclamation nutrient recycle, and toxicity control.

- **Inventor** - Inventor of Advanced Integrated Wastewater Ponding Systems. High Rate Ponds, Algatron, Photosynthetic Oxygenation, Porphyridium Cruentum.

- **Writer** - Professor Oswald has authored over 400 papers, articles and reports published in professional journals, books and trade publications throughout the world. A list of publications and reports since 1990 follows. The complete list since 1950 is available upon request.

## REFERENCES

Chen, P.H. (1987). *Factors Influencing Methane Fermentation of Micro-Algae*, Ph.D. dissertation, School of Public Health, University of California, Berkeley, pp. 256

Ergas, S., Lawver, R.A., Pfeiffer, W.J.T., and Schroeder, E.D. (1990). *Microbial Process for Removal of Selenium from Agricultural Drainage Water*, Report to the U.S. Bureau of Reclamation, Contract No. 9-FC-20-07720, pp. 67.

Gerhardt, M.B. and Oswald, W.J. (1990). *Microalgal-Bacterial Treatment for Selenium Removal from San Joaquin Valley Drainage Waters*, Final report to the Federal-State San Joaquin Valley Drainage Program, U.S. Bureau of Reclamation, Sacramento, California, pp. 242.

Gerhardt, M.B., Green, F.B., Newman, R.D., Lundquist, T.J., Tresan, R.B., and Oswald, W.J. (1991). "Removal of selenium using a novel algal-bacterial process," *Research Journal of the Water Pollution Control Federation*, July/August, pp. 799-805.

Lee, E.W. (1993). "Treatment, Reuse, and Disposal of Drain Waters," *Journal of Irrigation and Drainage Engineering*, Vol. 119, No. 3, pp. 501-513.

Lundquist, T.J., Gerhardt, M.B., Green, F.B., Tresan, R.B., Newman, R.D., and Oswald, W.J. (1994). "The algal-bacterial selenium removal system: mechanisms and field study," In: *Selenium in the Environment*, Frankenberger, W.T. and Benson S.M. (eds.), Pergamon Press, New York, New York, pp. 251-278.

Naylor, T. (1993). Personal communication, Microbio Resources, Inc., San Diego, California.

# Budget
(October 1, 1997 - September 30, 2000)

| | Monthly Rate | No of Months | | | % | 10/1/97-9/30/98 | 10/1/98-9/30/99 | 10/1/99-9/30/00 |
|---|---|---|---|---|---|---|---|---|
| **Personnel** | | | | | | | | |
| Prof. Oswald, PI- Research Recall | $10,522 | 12 cal yr. | | | 15% | $18,940 | $19,887 | $20,881 |
| Prof. Leighton, | $8,167 | 3 summer | | | 10% | $2,450 | $2,573 | $2,702 |
| Assistant Researcher | $4,817 | 12 cal. yr. | | | 75% | $43,353 | $44,220 | $45,104 |
| Assistant Specialist | $2,905 | 12 cal. yr. | | | 75% | $26,145 | $26,668 | $27,201 |
| Junior Specialist | $2,331 | 12 cal. yr. | | | 100% | $27,972 | $28,531 | $29,102 |
| Visiting Postdoc | $2,500 | 12 cal. yr. | | | 100% | | $30,000 | $30,000 |
| 3 GSR I | $2,253 | 9 ac.yr. | | | 50% | $30,416 | $31,024 | $31,644 |
| | $2,253 | 3 summer | | | 100% | $20,277 | $20,683 | $21,097 |
| | TOTAL PERSONNEL | | | | | $169,553 | $203,586 | $207,731 |
| **Employee Benefits** | | Rates Per Period | | | | | | |
| Principal Investigator, cal. yr. | | 1.93% | 1.93% | 1.93% | | $366 | $384 | $403 |
| Professor, summer | | 9.20% | 9.20% | 9.20% | | $225 | $237 | $249 |
| Other Academic Personnel | | 17.00% | 17.00% | 17.00% | | $16,570 | $22,001 | $22,339 |
| Graduate Student Researcher, ac. yr | | 1.40% | 1.40% | 1.40% | | $426 | $434 | $443 |
| Graduate Student Researcher, smr. | | 3.00% | 3.00% | 3.00% | | $608 | $620 | $633 |
| Student Health Ins. Program/per sem. | | $219 | $235 | $253 | | $1,314 | $1,410 | $1,518 |
| Full Fee Remission/per semester | | $1,978 | $2,176 | $2,394 | | $11,868 | $13,056 | $14,364 |
| Nonresident Tuition Remission/per sem. | | $4,492 | $4,941 | $5,435 | | $26,952 | $29,646 | $32,610 |
| | TOTAL EMPLOYEE BENEFITS | | | | | $58,329 | $67,788 | $72,559 |
| | TOTAL PERSONNEL & BENEFITS | | | | | $227,882 | $271,374 | $280,290 |
| **Subcontract** | | | | | | | | |
| Lawrence Berkeley Laboratory | | | | | | $20,919 | $20,919 | $20,919 |
| DWR | | | | | | $41,000 | $41,000 | $41,000 |
| Construction of ABSR Facility | | | | | | $900,000 | | |
| | TOTAL SUBCONTRACT | | | | | $961,919 | $61,919 | $61,919 |
| **Travel** | | | | | | | | |
| 2 RT/week to Los Banos (300 mi. RT @ $.24/mi.) | | | | | | $7,200 | | |
| 1 RT/week to Los Banos | | | | | | | $3,600 | $3,600 |
| | TOTAL TRAVEL | | | | | $7,200 | $3,600 | $3,600 |
| **Other Direct Costs** | | | | | | | | |
| Carbon Dioxide and Coagulants @ $160/day | | | | | | $58,400 | $58,400 | $58,400 |
| Reagent Costs and Waste | | | | | | $5,000 | $5,000 | $5,000 |
| copy charges | | | | | | $750 | $750 | $750 |
| Telephone charges | | | | | | $1,000 | $1,000 | $1,000 |
| Research Management Services | | | | | | $10,648 | $12,785 | $13,046 |
| | TOTAL OTHER DIRECT COSTS | | | | | $75,798 | $77,935 | $78,196 |
| | TOTAL DIRECT COSTS | | | | | $1,272,799 | $414,828 | $424,005 |
| **Indirect Costs** | | | | | | | | |
| 10.0% of Total Direct Costs | | | | | | $127,280 | $41,483 | $42,401 |
| | **TOTAL AMOUNT REQUESTED PER YEA** | | | | | $1,400,079 | $456,311 | $466,406 |
| | **TOTAL AMOUNT REQUESTED** | | | | | | | **$2,322,796** |

[1] Current salary rates shown. Subtotals include a projected 5% cost of living increase effective every October 1st.
[2] Current salary rates shown. Subtotals include a projected 2% cost of living increase effective every October 1st.

## COST BREAKDOWN TABLE

| Project Phase and Task | Direct Labor Hours | Direct Salary and Benefits | Overhead Labor (General, Admin and fee) | Service Contracts | Material and Acquisition Contracts | Miscellaneous and other Direct Costs | Total Costs |
|---|---|---|---|---|---|---|---|
| Task 1 | 10,719.27 | $210,790.85 | $117,734.00 | $57,275.08 | $832,500.00 | $76,773.15 | **$1,295,073.08** |
| Task 2 | 16,803.18 | $399,287.70 | $60,747.05 | $89,782.55 | $0.00 | $118,395.40 | **$668,212.70** |
| Task 3 | 1,158.84 | $27,583.20 | $4,194.20 | $6,191.90 | $0.00 | $8,166.55 | **$46,135.85** |
| Task 4 | 1,158.84 | $27,583.20 | $4,194.20 | $6,191.90 | $0.00 | $8,166.55 | **$46,135.85** |
| Task 5 | 1,158.84 | $28,029.00 | $4,240.10 | $6,191.90 | $0.00 | $8,179.60 | **$46,640.60** |
| Task 6 | 1,448.55 | $33,280.25 | $7,376.20 | $7,739.87 | $22,500.00 | $10,241.50 | **$81,137.82** |
| Task 7 | 2,317.68 | $52,991.80 | $12,678.25 | $12,383.80 | $45,000.00 | $16,406.25 | **$139,460.10** |
| TOTAL | 34,765.20 | $779,546.00 | $211,164.00 | $185,757.00 | $900,000.00 | $246,329.00 | **$2,322,796.00** |


I-005883

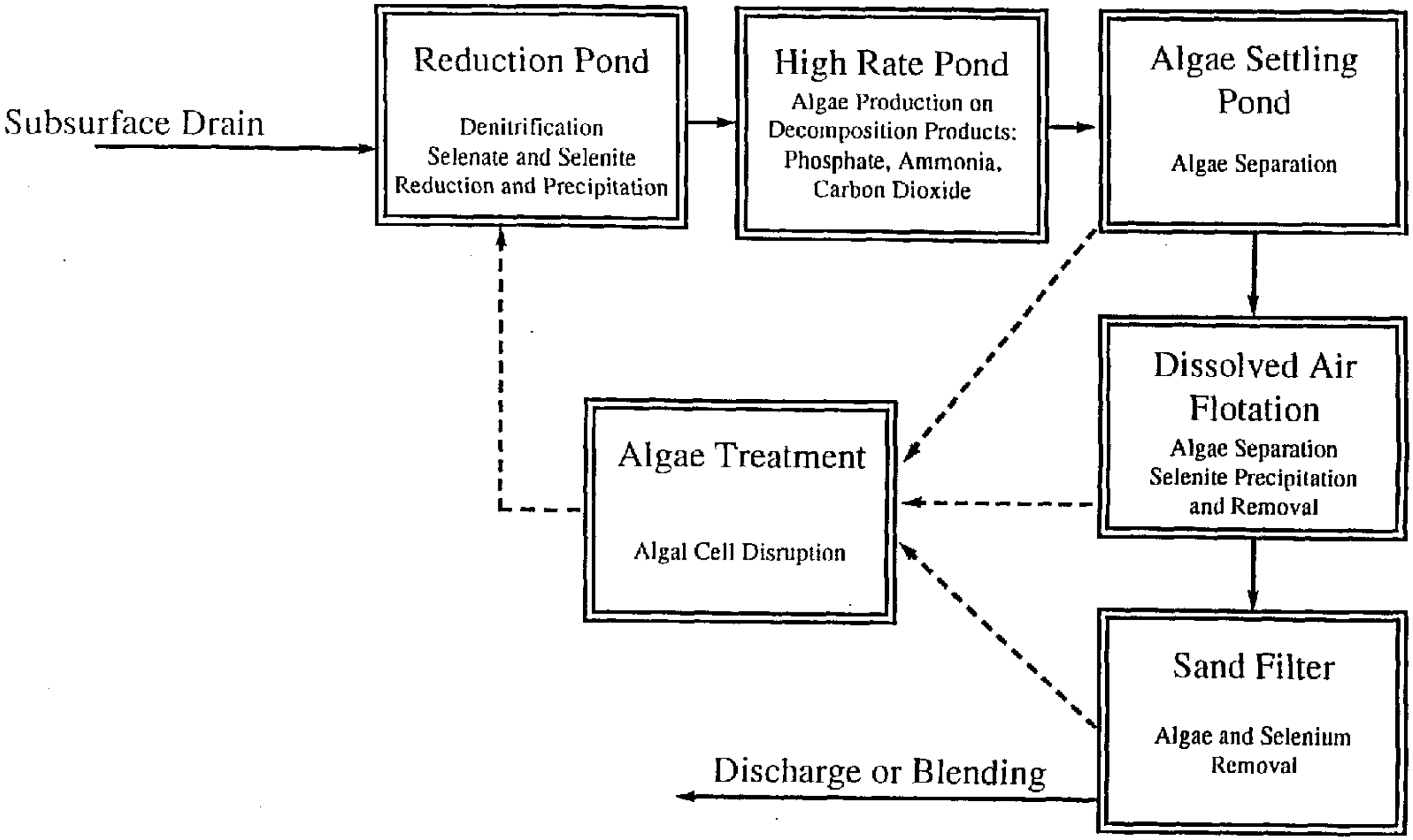


Figure 1. Flow schematic of the ABSR System.

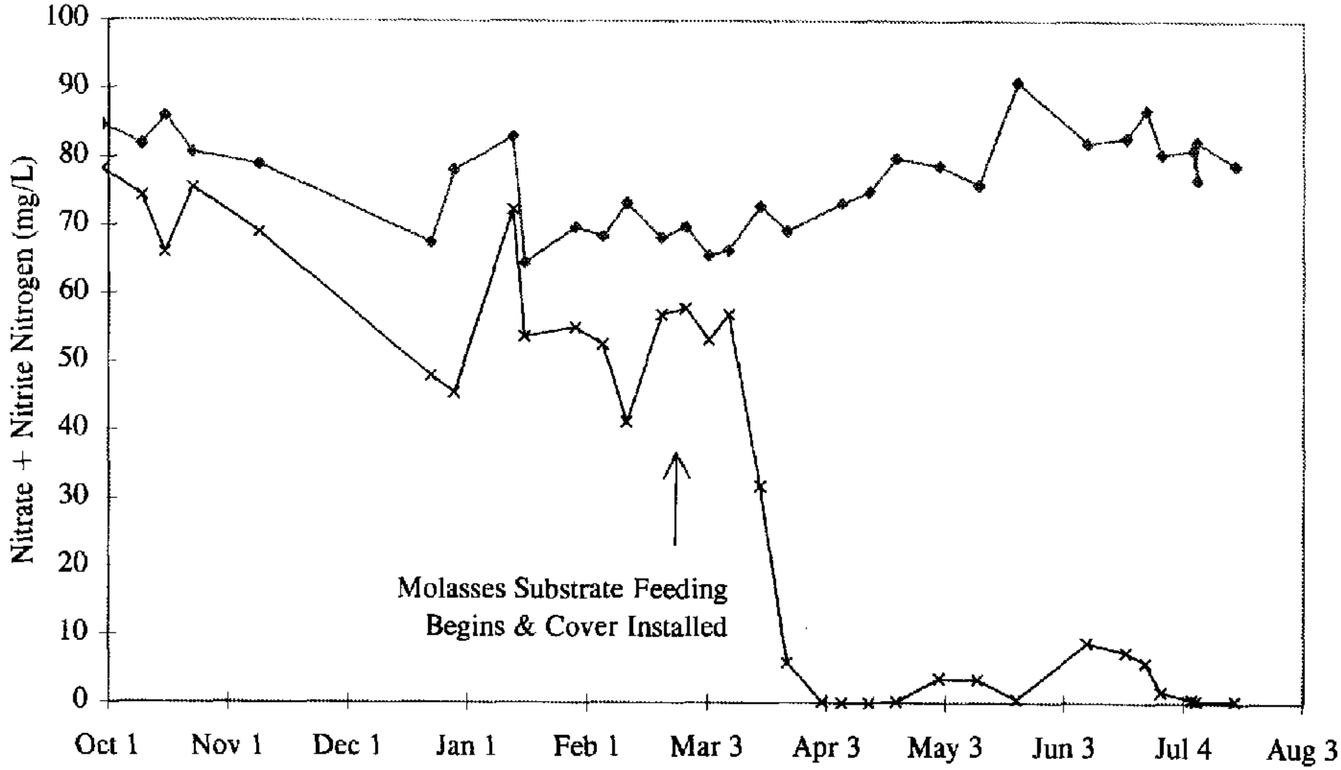


**Figure 2. Nitrate + nitrite nitrogen concentrations in the North Reduction Pond of the ABSR Facility at the Panoche Drainage District during 1996-1997.**

Influent    North Reduction Pond effluent

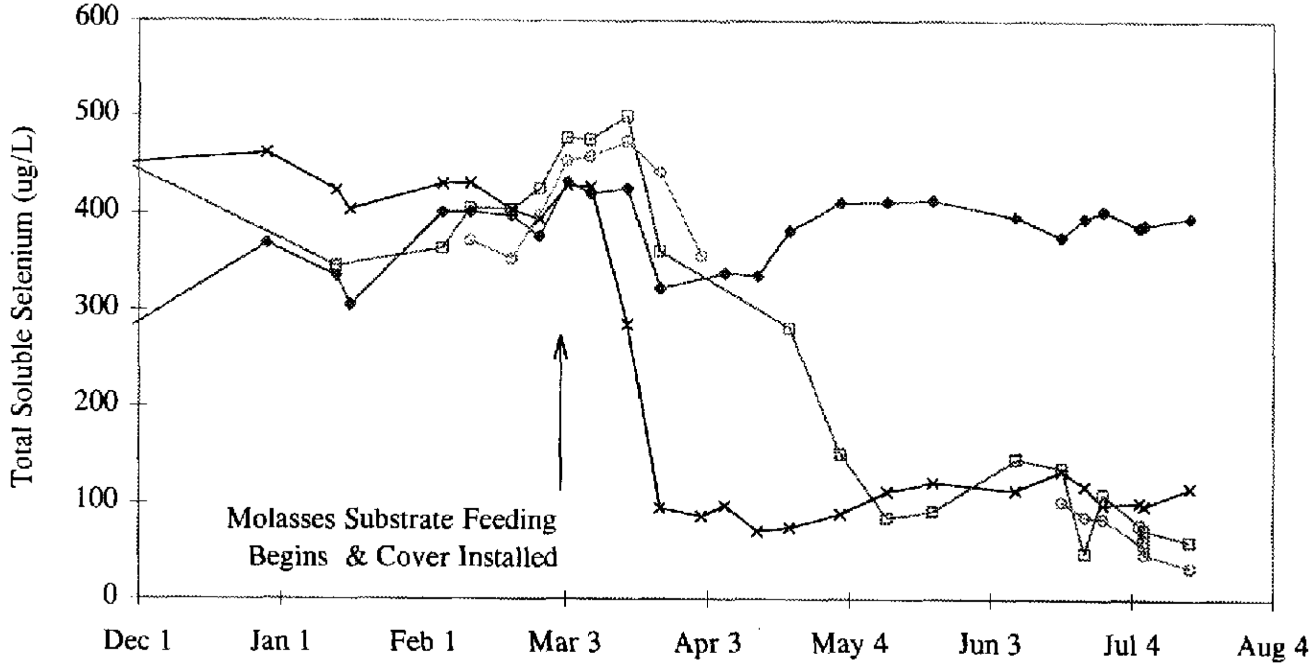


**Figure 3. Total soluble selenium concentrations in the North ABSR System at the Panoche Drainage District during 1996-1997.**

Influent — North Reduction Pond effluent — North High Rate Pond — North Settling Pond

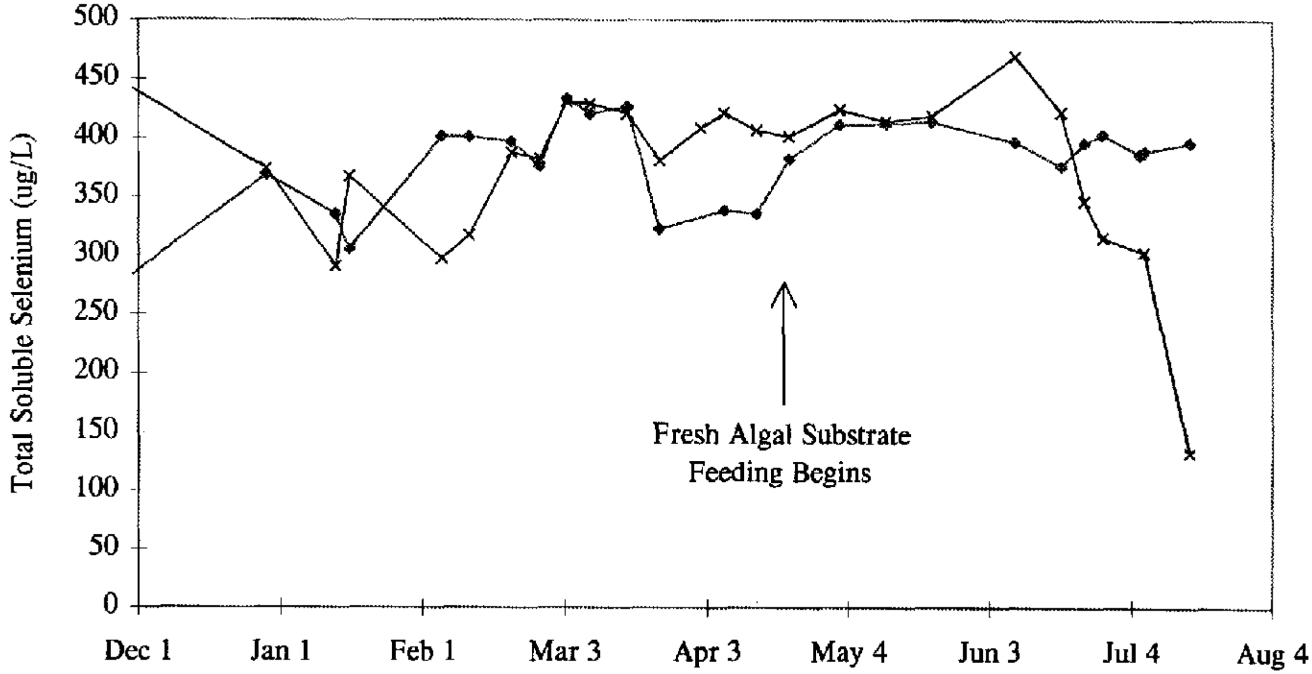


**Figure 4. Total soluble selenium concentrations in the South Reduction Pond of the ABSR Facility at the Panoche Drainage District during 1996-1997.**

Influent — South Reduction Pond effluent

Item 8

P1-270

# NONDISCRIMINATION COMPLIANCE STATEMENT

JUL 2 8 1997

COMPANY NAME

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

## CERTIFICATION

*I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California*

| | |
|---|---|
| OFFICIAL'S NAME: Lynn E. Deetz<br>Senior Research Administrator | |
| DATE EXECUTED: 7/28/97 | EXECUTED IN THE COUNTY OF: Alameda |
| PROSPECTIVE CONTRACTOR'S SIGNATURE: Lynn E Deetz | |
| PROSPECTIVE CONTRACTOR'S TITLE: Lynn E. Deetz<br>Senior Research Administrator | |
| PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA | |

F1-270 Item 11

Agreement No. ______

Exhibit ______

NONCOLLUSION AFFIDAVIT TO BE EXECUTED BY BIDDER AND SUBMITTED WITH BID FOR PUBLIC WORKS

STATE OF CALIFORNIA )

)ss

COUNTY OF Alameda )

Lynn E. Deetz
Senior Research Administrator
______ (name), being first duly sworn, deposes and

says that he or she is Lynn E. Deetz Senior Research Administrator Sponsored Projects Office University of California Berkeley Campus (position title) of

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA (the bidder)

the party making the foregoing bid that the bid is not made in the interest of, or on behalf of, any undisclosed person, partnership, company, association, organization, or corporation; that the bid is genuine and not collusive or sham; that the bidder has not directly or indirectly induced or solicited any other bidder to put in a false sham bid, and has not directly or indirectly colluded, conspired, connived, or agreed with any bidder or anyone else to put in a sham bid, or that anyone shall refrain from bidding; that the bidder has not in any manner, directly or indirectly, sought by agreement, communication, or conference with anyone to fix the bid price of the bidder or any other bidder, or to fix any overhead, profit, or cost element of the bid price, or of that of any other bidder, or to secure any advantage against the public body awarding the contract of anyone interested in the proposed contract; that all statements contained in the bid are true; and, further, that the bidder has not, directly or indirectly, submitted his or her bid price or any breakdown thereof, or the contents thereof, or divulged information or data relative thereto, or paid, and will not pay, any fee to any corporation, partnership, company, association, organization, bid depository, or to any member or agent thereof to effectuate a collusive or sham bid.

DATED: 7/28/97 By Lynn E Deetz (person signing for bidder)

Subscribed and sworn to before me on

N/A

______ (Notary Public)

(Notarial Seal)